CHAPTER 5

OVERLAY PAVEMENT DESIGN

5-1.. General. Two general types of overlay pavement are considered: rigid and nonrigid. The procedures described will use rigid overlays to strengthen existing rigid or flexible pavements and nonrigid overlays to strengthen existing rigid pavements. Procedures are presented for the design of jointed concrete (JC), jointed reinforced concrete (JRC), fibrous concrete (FC), and nonrigid overlays. Nonrigid overlays include both flexible (nonstabilized base and bituminous concrete wearing course) and all-bituminous concrete for strengthening existing JC or JRC pavements. Flexible overlays will be used only when the nonstabilized aggregate base course can be positively drained. Resurfacing of rigid pavements with thin, bonded rigid overlays (less than 4 inches) are not to be considered for strengthening of existing pavements.

5-2. Site investigations. Explorations and tests of the existing pavement will be made to determine the structural condition of the existing pavement prior to overlay, assess the required physical properties of the existing pavement and foundation materials, and locate and analyze all existing areas of defective pavement and subgrade that will require special treatment. The determination of the structural condition and required physical properties of the existing pavement will depend upon the type of overlay used as described in subsequent paragraphs. An investigation will be conducted to determine whether there are any voids under the existing rigid pavement. This investigation is especially important if there has been, or is, any evidence of pumping or bleeding of water at cracks, joints, or edges of the existing rigid pavement. If voids are found under the existing rigid pavements, they will be grouted before the overlay is placed. The results of the investigation, especially the nondestructive tests, may show rather large variations in the strength of the existing pavement and may lead to more extensive testing to determine the cause of the variation. It will then be necessary to determine the feasibilty and economics of using a variable thickness overlay, basing the design on the lower strength pavement section, or removing and replacing the low-strength pavement areas.

5-3. Preparation of existing pavement. The preparation of the existing pavement prior to overlay will depend upon the type of overlay, as follows:

a. Rigid overlay. Overlay thickness criteria are presented for two conditions of bond between the rigid overlay and existing rigid pavement: partially and nonbonded. The partially bonded condition is obtained when concrete is cast directly on concrete with no special efforts to achieve or destroy bond. The nonbonded condition is obtained when the bond is prevented by an intervening layer of

material. When a partially bonded rigid overlay is to be used, the existing rigid pavement will be cleaned of all foreign matter (oil, paint, etc.), spalled concrete, extruded joint seal, bituminous patches, or anything else that would act as a bond-breaker between the overlay and existing rigid pavement. When a nonbonded rigid overlay is being used, the existing rigid pavement will be cleaned of all loose particles and covered with a leveling or bond-breaking course of bituminous concrete, sand-asphalt, heavy building paper, polyethylene, or other similar stable material. The bond-breaking medium generally should not exceed a thickness of about 1 inch except in the case of leveling courses where greater thicknesses may be necessary. When a rigid overlay is being applied to an existing flexible pavement, the surface of the existing pavement will be cleaned of loose materials and any potholing or uneveness, exceeding about 1 inch, will be repaired by localized patching or the application of a leveling course using bituminous concrete, sand-asphalt, or similar material.

b. Nonrigid overlay. When a flexible overlay is used, no special treatment of the surface of the existing rigid pavement will be required, other than the removal of loose material. When an all-bituminous concrete overlay is used, the surface of the existing rigid pavement will be cleaned of all foreign matter, spalled concrete, fat spots in bituminous patches, and extruded soft or spongy joint seal material. Joints or cracks less than 1 inch wide in the existing rigid pavement will be filled with joint sealant. Joints or cracks that are 1 inch or greater in width will be cleaned and filled with an acceptable bituminous mixture (such as sand-asphalt) which is compatible with the overlay. Wedge courses of bituminous concrete will be used to bring the existing rigid pavement to proper grade when required. Prior to placing the all-bituminous concrete overlay, a tack coat will be applied to the surface of the existing pavement.

5-4. Condition of existing rigid pavement. The support that the existing rigid pavement will provide to an overlay is a function of its structural condition just prior to the overlay. In the overlay design equations, the structural condition of the existing rigid pavement is assessed by a condition factor C. The selection of a value of C is a judgment decision, which is somewhat arbitrary; however, to provide a more uniform assessment of the value, the following conditions are defined. Interpolation of C values between those shown may be used if it is considered necessary to more accurately define the existing structural condition.

a. Rigid overlay.

(1) Condition of existing JC pavement.

C = 1.00 - pavements in the trafficked areas are in good condition with little or no structural cracking due to load.

C = 0.75 - pavements in the trafficked areas exhibit initial cracking due to load but no progressive cracking or faulting of joints or cracks.

C = 0.35 - pavements in the trafficked areas exhibit progressive cracking due to load accompanied by spalling, raveling, or faulting of cracks and joints.

(2) Condition of existing JRC pavements.

C = 1.00 - pavements in the trafficked areas are in good condition with little or no short-spaced transverse (1- to 2-foot) cracks, no longitudinal cracking, and little spalling or raveling along cracks.

C = 0.75 - pavements in the trafficked areas exhibit short-spaced transverse cracking but little or no interconnecting longitudinal cracking due to load and only moderate spalling or raveling along cracks.

C = 0.35 - pavements in the trafficked areas exhibit severe short-spaced transverse cracking and interconnecting longitudinal cracking due to load, severe spalling along cracks, and initial punchout-type failures.

b. Nonrigid overlay.

(1) Condition of existing JC pavements.

C = 1.00 - pavements in the trafficked areas are in good condition with some cracking due to load but little or no progressive-type cracking.

C = 0.75 - pavements in the trafficked area exhibit progressive cracking due to load and spalling, raveling, and minor faulting at joints and cracks.

C = 0.50 - pavements in the trafficked areas exhibit multiple cracking along with raveling, spalling, and faulting at joints and cracks.

(2) Condition of existing JRC pavement.

C = 1.00 - pavements in trafficked areas are in good condition but exhibit some closely spaced

load-induced transverse cracking, initial interconnecting longitudinal cracks, and moderate spalling or raveling of joints and cracks.

C = 0.75 - pavements in trafficked areas exhibit numerous closely spaced load-induced transverse and longitudinal cracks, rather severe spalling or raveling, or initial evidence of punchout failures.

5-5. Rigid overlay of existing rigid pavement. There are two basic equations for the design of rigid overlays which depend upon the degree of bond that develops between the overlay and existing pavement: partially bonded and nonbonded. The partially bonded equation will be used when the rigid overlay is to be placed directly on the existing pavement. It requires the lesser thickness of overlay and will be used when possible. A bond-breaking medium and nonbonded equation will be used when a JC overlay is used to overlay an existing JRC pavement, when a JC overlay is being used to overlay an existing JC pavement that has a condition factor $C \leq 0.35$, and when matching joints in a JC overlay with those in the existing JC pavement causes undue construction difficulties or results in odd-shaped slabs.

a. JC overlay.

(1) Thickness determination. The required thickness h_{doc} of JC overlay will be determined from the following equations:

Partially bonded:

$$h_{doc} = \sqrt[1.4]{h_{dc}^{1.4} - C\left(\frac{h_{dc}}{h_{dec}}\, h_{Ec}\right)^{1.4}}$$

Nonbonded:

$$h_{doc} = \sqrt{h_{dc}^{2} - C\left(\frac{h_{dc}}{h_{dec}}\, h_{Ec}\right)^{2}}$$

where h_{dc} and h_{dec} are design thicknesses of JC pavement determined in accordance with paragraph 2-2 using the design flexural strength of the overlay and measured flexural strength of the existing rigid pavement, respectively; the modulus of soil reaction k of the existing rigid pavement foundation; and the design loading, traffic area, and pass level needed for overlay design. The ratio h_{dc}/h_{dec} is an adjustment factor used only when the difference in the flexural strength of the concrete overlay and existing rigid pavement exceeds 100 psi. The factor h_{Ec} represents the thickness of JC pavement equivalent to load-carrying capacity to the thickness of existing rigid pavement. If

the existing rigid pavement is JC (h_{ec}), then $h_{Ec} = h_{ec}$. However, if the existing rigid pavement is JRC (h_{er}), the value of h_{Ec} must be determined from figure 3-1 using the percent of reinforcing steel, S, and the thickness h_{er}. The minimum thickness of JC overlay will be 6 inches.

(2) Jointing. For all partially bonded JC overlays, joints will be provided in the overlay to coincide with all joints in the existing rigid pavement. It is not necessary for joints in the overlay to be of the same type as joints in the existing pavement. When it is impractical to match the joints in the overlay to joints in the existing rigid pavement, either a bond-breaking medium will be used and the overlay designed as a nonbonded overlay or the overlay will be reinforced over the mismatched joints in accordance with paragraph 3-3b. Should the mismatch of joints become severe, a JRC overlay design (b below) should be considered as an economic alternative to the use of a nonbonded JC overlay. For nonbonded JC overlays, the design and spacing of transverse contraction joints will be in accordance with paragraph 2-3a. For both partially bonded and nonbonded JC overlays, the longitudinal construction joints will be doweled using the dowel size and spacing given in table 2-2. Any contraction joint in the overlay that coincides with an expansion joint in the existing rigid pavement within the prescribed limits of a Type A traffic area will be doweled. Joint sealing for JC overlays will conform to the requirements of paragraph 2-3f.

b. JRC overlay. A JRC overlay may be used to strengthen either an existing JC or JRC pavement. Generally, the overlay will be designed as a partially bonded overlay. The nonbonded overlay design will be used only when a leveling course is required over the existing pavement. The reinforcement steel for JRC overlay will be designed and placed in accordance with paragraph 3-5.

(1) Thickness determination. The required thickness h_{dor} of JRC overlay will be determined using figure 3-1 after the thickness of JC overlay (h_{doc}) has been determined using the appropriate overlay equation. Then, with a value for h_{doc}, either the thickness h_{dor} can be selected and the required percent steel, S, determined, or S can be selected and h_{dor} determined from figure 3-1. The minimum thickness of JRC overlay will be 6 inches.

(2) Jointing. Whenever possible, the longitudinal construction joints in the overlay should match the longitudinal joints in the existing pavement. All longitudinal joints will be of the butt-doweled type with dowel size and spacing designated in accordance with paragraph 2-3 using the thickness h_{dor}. It is not necessary for transverse joints in the overlay to match joints in the existing pavement; however, when practical, the joints should be matched. The maximum spacing of transverse contraction joints will be determined in accordance with figure 3-2 or paragraph 2-3a, but it will not exceed

100 feet regardless of thickness of pavement or percent steel used. Joint sealing for JRC pavements will conform to the requirements of paragraph 2-3f.

c. JFC overlay. A JFC overlay may be used to strengthen either an existing JC or JRC pavement. The mix proportioning of the JFC overlay will follow the considerations outlined in paragraph 4-3.

(1) Thickness determination. The required thickness h_{dof} of JFC overlay will be determined using the following equations. Normally, the partially bonded equation will be used; however, in cases of extremely faulted or uneven existing pavement surfaces, a leveling course may be required and the design of the overlay will be made using the nonbonded overlay equation.

Partially Bonded:

$$h_{dof} = 0.75 \sqrt[1.4]{h_{dc}^{1.4} - C\left(\frac{h_{dc}}{h_{dec}} h_{Ec}\right)^{1.4}}$$

Nonbonded:

$$h_{dof} = 0.75 \sqrt{h_{dc}^{2} - C\left(\frac{h_{dc}}{h_{dec}} h_{Ec}\right)^{2}}$$

where h_{dc} and h_{dec} are design thickness of JC pavement determined in accordance with paragraph 2-2 using the design flexural strength of the JFC overlay and flexural strength of the existing rigid pavement, respectively, the modulus of soil reaction k of the existing rigid pavement foundation, and the design loading, traffic area, and pass level needed for the overlay design. The ratio h_{dc}/h_{dec} will normally be required because the flexural strength of the JFC will generally exceed the flexural strength of the existing rigid pavement by more than 100 psi. The factor h_{Ec} represents the thickness of JC pavement equivalent to the thickness of the existing rigid pavement. If the existing rigid pavement is JC (h_{Ec}), then $h_{Ec} = h_{ec}$; however, if the existing rigid pavement is JRC (h_{er}), h_{Ec} must be determined from figure 3-1 using the values of h_{er} and the percent of reinforcing steel, S. The minimum thickness of JFC overlay will be 4 inches.

(2) Jointing. In general, the joint types and designs discussed in paragraph 2-3 and the maximum spacing shown in paragraph 4-6 apply to JFC overlays. It is not essential that joints be provided in the JFC overlays to coincide with joints in the existing rigid pavement; however, the matching of longitudinal joints is desirable. Longitudinal construction joints will be the butt-doweled type, and dowels will be required in transverse contraction joints exceeding 50-foot spacings. Sealing of joints in JFC overlays will be in accordance with paragraph 4-6.

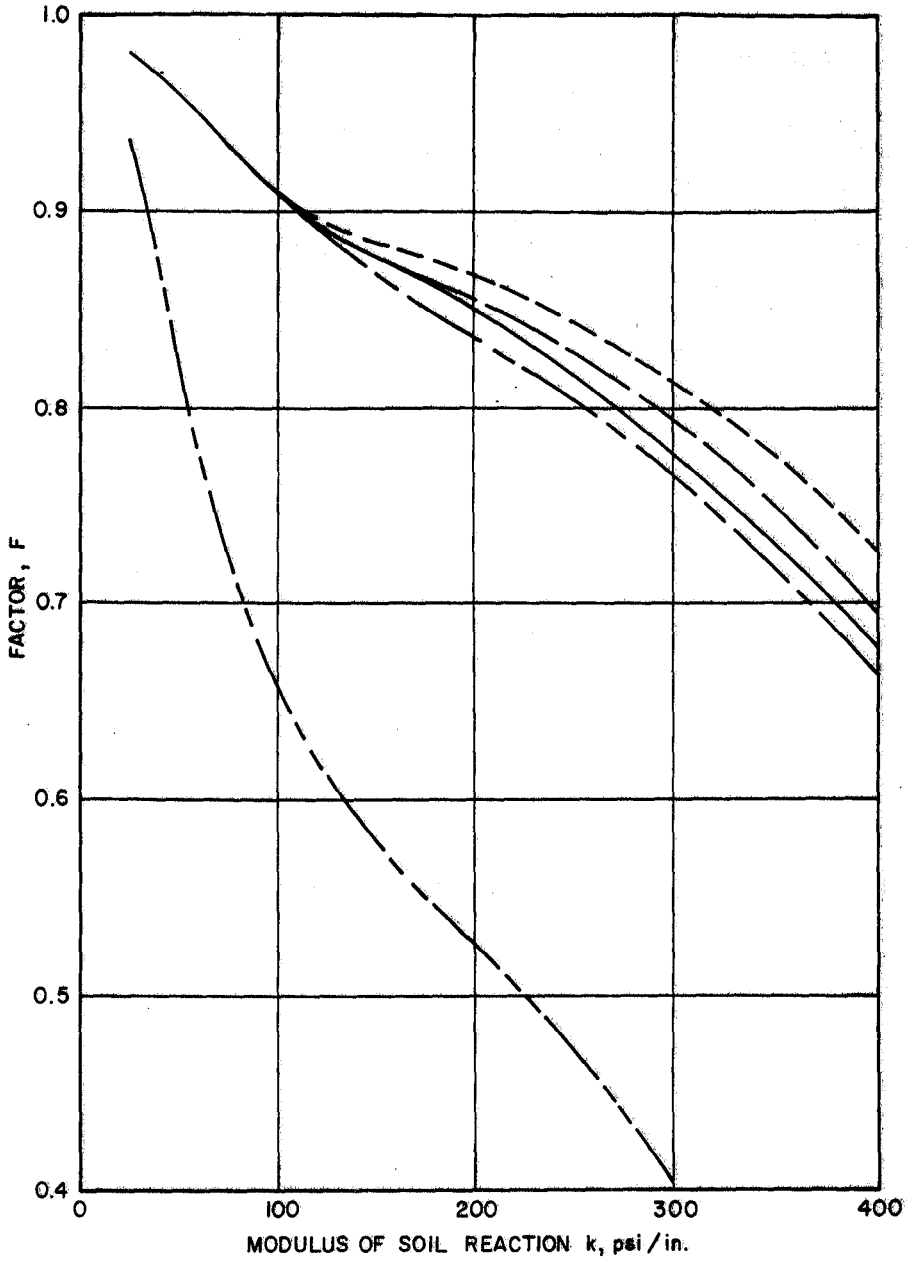
5-6. Rigid overlay of existing flexible or existing composite pavement. Any type of rigid overlay (JC, JRC, or JFC) may be used to strengthen an existing flexible or composite pavement. The existing pavement is considered to be a composite pavement when it is composed of a rigid base pavement that has been strengthened with 4 inches or more of nonrigid (flexible or all-bituminous) overlay. If the nonrigid overlay is less than 4 inches, the rigid overlay is designed using the nonbonded overlay equation as outlined in paragraph 5-5. The design of the rigid overlay will follow the procedures outlined in chapters 2 through 4 of this manual. The strength afforded by the existing pavement will be characterized by the modulus of soil reaction k performed in accordance with paragraph 1-9a but in no case will a k value greater than 500 psi per inch be used for design. When figure 1-3 is used to estimate the k value at the surface of the existing flexible pavement, the bituminous concrete portion will be assumed to be unbound base material.

5-7. Nonrigid overlay of existing rigid pavement. Two types of nonrigid overlay, all-bituminous concrete overlay and flexible overlay, may be used with certain reservations to strengthen an existing rigid pavement.

a. Thickness determination. Regardless of the type of nonrigid overlay, the required thickness t_o will be determined by the following equation:

$$t_o = 2.5(Fh_{dec} - Ch_{Ec})$$

where h_{dec} is the design thickness of JC pavement determined from chapter 2 using the flexural strength R of the concrete in the existing rigid pavement, the modulus of soil reaction k of the existing pavement, and the overlay design class. The factor h_{Ec} represents the thickness of JC pavement equivalent in load-carrying ability to the thickness of existing rigid pavement. If the existing rigid pavement is JC (h_{ec}), then $h_{Ec} = h_{ec}$; however, if the existing rigid pavement is JRC (h_{er}), the value of h_{Ec} must be determined from figure 3-1 using the thickness h_{er} and the percentage of reinforcing steel, S. F is a factor, determined from figure 5-1, that projects the cracking that may be expected to occur in the base pavement during the design life of the overlay, and C is a coefficient based upon the structural condition of the existing rigid pavement (para 5-4). The computed value of t_o will be rounded to the nearest multiple of 1 inch. The minimum value of t_o used for strengthening purposes will be 2 inches for all Type D traffic areas and overruns, 3 inches for Types B and C traffic areas in light-load pavements, and 4 inches for all others. In certain instances, the nonrigid overlay design equation will indicate thickness requirements less (sometimes negative values) than the minimum values, and in such cases the minimum thickness requirement will be used.



LEGEND

LOAD	TRAFFIC AREAS
Heavy	A, B, and C
Medium	A, B, and C
Light	B and C
Short fields	A
Heavy and Medium	D (and overruns for all loads)

NOTE: Minimum value of F = 0.40
for k > 400 use the F value
for k = 400

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FIGURE 5-1. CONDITION FACTOR F VERSUS MODULUS OF SOIL REACTION K

b. Alternate thickness design procedure. When strengthening existing rigid pavements that exhibit low flexural strength (less than 500 psi) or that are constructed on high-strength foundations ("k" exceeding 200 psi per inch), it is found that the flexible pavement design procedure in EM 1110-3-141 may indicate a lesser required overlay thickness than the overlay design formula in paragraph a. above. For these conditions, the overlay thickness will be determined by both methods, and the lesser thickness used for design. For the flexible pavement design procedure, the existing rigid pavement will be considered to be either an equivalent thickness of all-bituminous concrete (equivalency factor of 1.15 for base and 2.3 for subbase), and the total pavement thickness determined based upon the subgrade CBR. Any existing base or subbase layers will be considered as corresponding layers in the flexible pavement. The thickness of required overlay will then be the difference between the required flexible pavement thickness and the combined thicknesses of existing rigid pavement and any base or subbase layers above the subgrade.

c. All-bituminous overlay. The all-bituminous overlay will be composed of hot-mix bituminous concrete. A tack coat is required between the existing rigid pavement and the overlay. The all-bituminous overlay is the preferred nonrigid type overlay to lessen the danger of entrapped moisture in the overlay.

d. Flexible overlay. The flexible overlay will be composed of hot-mix bituminous concrete and high-quality (CBR = 100) crushed aggregate base provided positive drainage of the base course is achieved. The bituminous concrete will meet the minimum thickness requirements of EM 1110-3-141. The crushed aggregate base will have a minimum thickness of 4 inches. If the design thickness t_o of nonrigid overlay is less than that required by the minimum thickness of bituminous concrete and base course, the overlay will be designed as an all-bituminous overlay.

e. Jointing. Normally, joints, other than those required for construction of a bituminous concrete pavement, will not be required in nonrigid overlays of existing rigid pavements. It has been experienced that the lower viscosity (or higher penetration grade) asphalts are less likely to experience reflection cracking at joints. Therefore, the lowest viscosity grade asphalt that will provide sufficient stability during high temperatures should be used.

5-8. Overlays in frost regions. Whenever the subgrade is subject to frost action, the design will meet the requirements for frost action stated in EM 1110-3-138. The design will conform to frost requirements for rigid pavements. If subgrade condition will produce detrimental nonuniform frost heaving, overlay pavement design will not be considered unless the combined thickness of overlay and existing pavement is sufficient to prevent substantial freezing of the subgrade.